Report No. RR-34

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Dynamic Simulations Laboratory
Research Division
Research and Engineering Directorate

DIGITAL COMPUTER PROGRAM

FOR

CONVENTIONAL BALLISTIC EVALUATION

by

Mary Archambault

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6 April 1961

Project No. 5510.11.270

D/A Project No. 572-01-001

Authenticated: Fred Pradko

U. S. Army Ordnance Tank-Automotive Command
1501 Beard
Detroit 9, Michigan

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ABSTRACT

This report presents a digital computer program for (1) determining the range at which an armored vehicle is vulnerable to rounds striking a specified point on its surface and for (2) determining the armor thickness required for protection at a specified range and angle of attack.

TABLE OF CONTENTS

LIST OF ILLUSTRATIONS

PROJECT TITLE: DIGITAL COMPUTER PROGRAM FOR CONVENTIONAL BALLISTIC EVALUATION

INTRODUCTION:

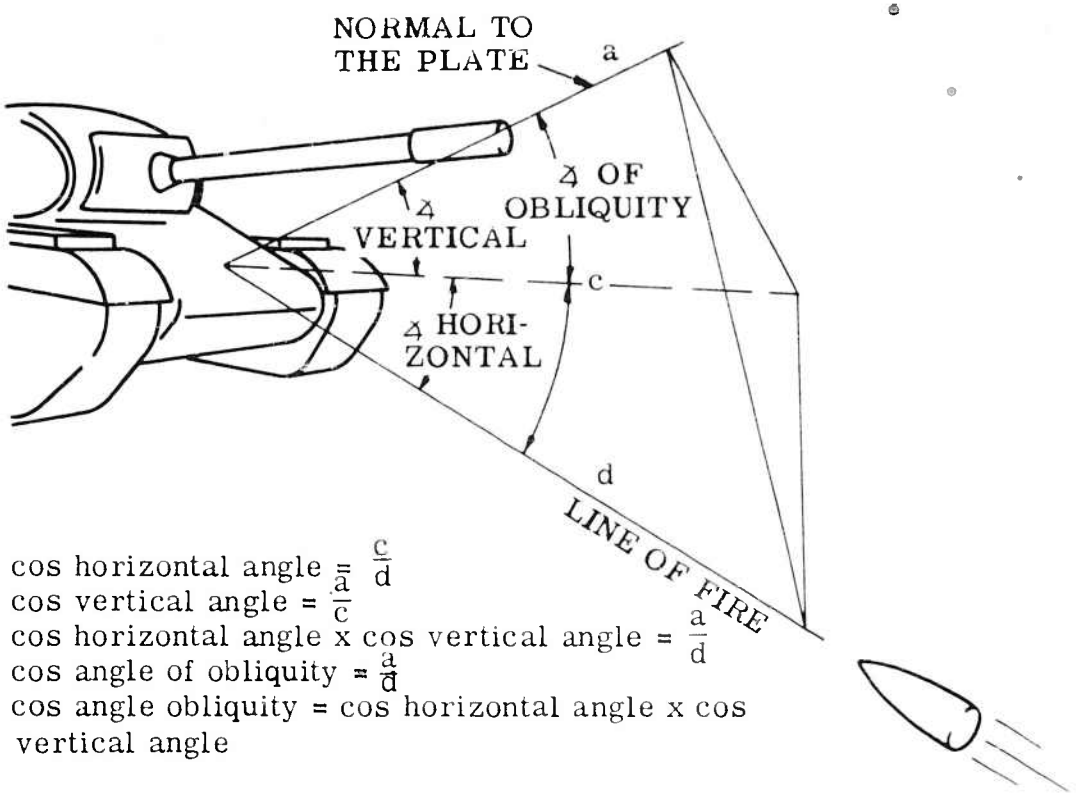
A high speed computer program has been developed for the Electrodata 204 digital computer which will determine the range at which a vehicle is vulnerable to rounds striking a specified point on its surface from a particular angle of attack, or conversely the armor thickness required for protection at a specified range and angle of attack.

OBJECTIVE:

Develop a computer program to rapidly and accurately furnish basic conventional ballistic evaluations of armored combat vehicles.

DISCUSSION:

It has been found that sloping armor from the vertical results in a greater resistance to penetration. The armor may reject or deflect the projectile, or offer sufficient depth of material to the incoming round to greatly decrease the residual velocity for penetration. Obliquity in itself is not entirely dependent on the slope of the plate. In the event the line of fire is angular to the plate, it would have the same effect as tilting the plate to that angle. In most cases a compound condition exists in which there is angular fire at a sloped plate. The angle of obliquity is defined as the angle between the line of fire and the normal to the plate.



cos horizontal angle = $\frac{c}{d}$
cos vertical angle = $\frac{a}{c}$
cos horizontal angle x cos vertical angle = $\frac{a}{d}$
cos angle of obliquity = $\frac{a}{d}$
cos angle obliquity = cos horizontal angle x cos vertical angle

FIGURE 1. COMPUTATION OF ANGLE OF OBLIQUITY

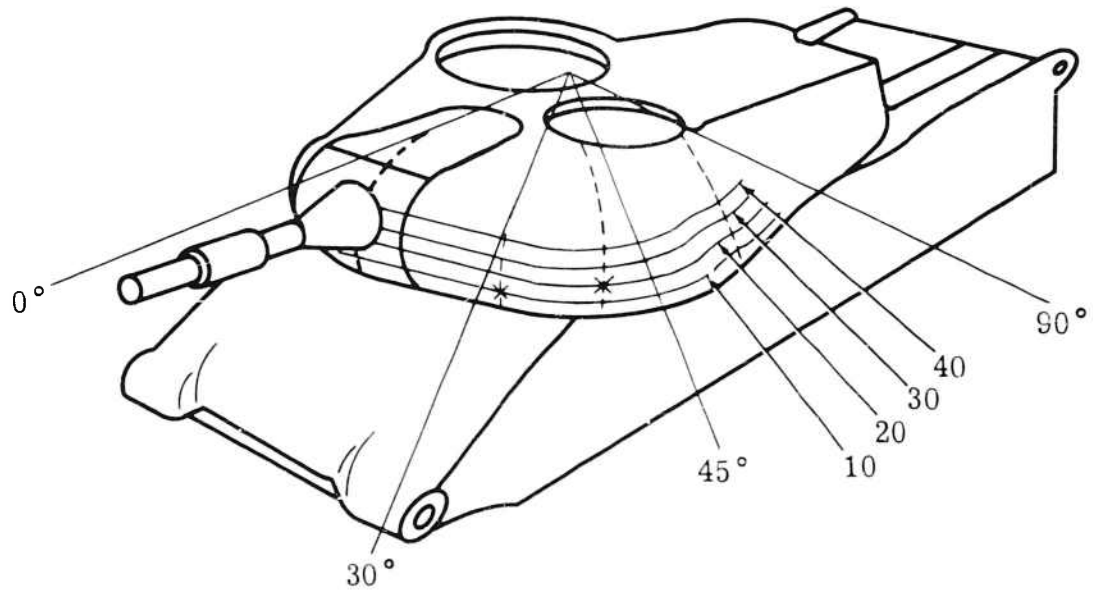


FIGURE 2. DESIGNATING SHELL IMPACT LOCATION

As shown in figure 1, the cosine of the angle of obliquity is a function of the angle of attack (horizontal angle) and the inclination of the plate (vertical angle). Knowing the horizontal and vertical angle under any direction of attack, the obliquity can then be determined by the cosine law. In the case of a standard plate, the thickness is measured along the normal at the point under consideration.

In ballistic penetration studies, prior to any computer determinations, the angle of attack must be designated, i.e., it may be frontal, 30° left or right flank, 45° left or right flank, etc. In addition, the shell impact location is necessary. This can be specified on the tank contour by dividing the turret or hull from top to bottom into horizontal sections, and dividing it radially in degrees from the center line as depicted in figure 2.

It is then possible to consider, for example, a projectile which strikes the left flank at reference points 10, 30°, or 20, 45°, etc.

It was the purpose of this program to ascertain the range at which the armor could be penetrated under any given thickness-obliquity combination and condition of attack. In addition, this program affords a better approach to ballistic design, for it will determine the armor thickness necessary to afford protection at various specified points.

COMPUTER PROGRAM SEQUENCE:

Utilizing basic input data of the horizontal angle, vertical angle and the thickness, the program computes the secant of the angles plus the secant of the angle of obliquity since the thickness curves for the various rounds are in terms of secants rather than cosines. A triple interpolation scheme was developed specifically for this program to go from secants to thickness and then to vulnerability range which is printed out in both meters and yards.

A similar program, plus a reverse interpolation, is utilized to go backward from range to secant to thickness in the second approach to determine safe armor against projectile penetrating power.

DATA:

Input data required by this program is outlined in Appendix B. Range or thickness (whichever is necessary) is machine interpolated for the desired conditions from range-secant-thickness curves which must be properly stored in the computer memory as data. This is in accordance with the procedure established in Appendix C, Coding. The angles, ranges, and thicknesses must be within the area defined by the curves. Interpolation is always based on the lower of the two values considered.

RESULTS:

Applying the proper input information, vehicle vulnerability ranges and design thickness requirements, as outlined in the DISCUSSION, can be quickly determined. Actual computer time is only a few seconds for each reference point considered. In addition, vehicles can be compared with respect to effective standoff distance from a particular type of attack.

Results are in floating point. For a sample of program output, see Appendix D.

Identifying information, such as vehicle designation, attack position, type of projectile, etc., was not incorporated in the output, since such details are variable factors.

APPENDIX A

OPERATING INSTRUCTIONS

1. Type identification material desired.
2. Set margins. Output on page. Print headings from tape.
3. Read in subroutine and interpolation tape.
4. Read in curve data.
5. Read in program tape.
6. Read in, or insert from keyboard, first set of data.
7. 6 0000 20 3000

Steps 6 and 7 are repeated for additional data.

APPENDIX B

INPUT DATA

1. To calculate range

   a. A data tape for the curves developed according to the scheme for range (Appendix C).

   b. Input parameters

      1500 horizontal angle in degrees
      1501 vertical angle in degrees
      1502 thickness

2. To calculate thickness

   a. A data tape for thickness developed according to the scheme for thickness (Appendix C).

   b. Input parameters

      1500 horizontal angle in degrees
      1501 vertical angle in degrees
      1502 range in meters

APPENDIX C

CODING

RANGE PROGRAM

(HORIZONTAL AND VERTICAL ANGLES, AND THICKNESS, FURNISHED)

```
3000  00000 64 1500
3001  00000 32 1503        radians
3002  00000 31 2000        → cos routine
3003  00001 12 1505        cos horizontal angle
3004  00000 64 1501
3005  00000 32 1503
3006  00000 31 2000
3007  00001 12 1506        cos vertical angle
3008  00000 32 1505
3009  00001 12 1507
3010  00000 64 1504
3011  00000 03 1507
3012  00004 12 0407        see angle obliquity
3013  00000 64 1502
3014  00001 12 0408        thickness
3015  00000 64 1508
3016  00000 02 1045
3017  00000 20 1000        → interpolation routine
3018  00000 64 1500        ←
3019  00000 03 0510        horizontal angle

3020  00000 64 1505
3021  00000 03 0310        cos horizontal angle
3022  00000 64 1501
3023  00000 03 0310        vertical angle
3024  00000 64 1506
3025  00000 03 0310        cos vertical angle
3026  00000 64 1507
3027  00000 03 0310        cos angle obliquity
3028  00000 64 0407
3029  00000 03 0310        secant angle obliquity
3030  00000 64 1502        thickness
3031  00000 03 0310
3032  00000 64 1203        range (meters)
3033  00000 03 0310
3034  00000 32 1509
3035  00000 03 0310        range (yards)
3036  00000 03 9999
```

STORAGE

```
1500  00000 00 0000        horizontal angle
1501  00000 00 0000        vertical angle
1502  00000 00 0000        thickness
1503  04917 45 3200
1504  05110 00 0000
1505  00000 00 0000        cos horizontal angle
1506  00000 00 0000        cos vertical angle
1507  00000 00 0000        cos angle obliquity
1508  00000 20 3018
1509  05110 93 6110        conversion to yards
```

THICKNESS PROGRAM

(HORIZONTAL AND VERTICAL ANGLES, AND RANGE, FURNISHED)

```
3000  00000 64 1500
3001  00000 82 1503          radians
3002  00000 31 2000          → cos routine
3003  00001 12 1505          cos horizontal angle
3004  00000 64 1501
3005  00000 82 1503
3006  00000 31 2000
3007  00001 12 1506          cos vertical angle
3008  00000 82 1505
3009  00001 12 1507
3010  00000 64 1504
3011  00000 83 1507
3012  00001 12 0408          secant angle obliquity
3013  00000 64 1502          range
3014  00001 12 0407
3015  00000 64 1508
3016  00000 02 1045
3017  00000 20 1000          → interpolation routine
3018  00000 64 1500          ←
3019  00000 03 0510          horizontal angle

3020  00000 64 1505
3021  00000 03 0310          cos horizontal angle
3022  00000 64 1501
3023  00000 03 0310          vertical angle
3024  00000 64 1506
3025  00000 03 0310          cos vertical angle
3026  00000 64 1507
3027  00000 03 0310          cos angle obliquity
3028  00000 64 0408
3029  00000 03 0310          secant angle obliquity
3030  00000 64 1502          range (meters)
3031  00000 03 0310
3032  00000 82 1509          range (yards)
3033  00000 03 0310
3034  00000 64 1263
3035  00000 03 0310          thickness
3036  00000 08 9999
```

RANGE PROGRAM

(OBLIQUITY AND THICKNESS FURNISHED)

```
3000  00000 64 1500      angles of obliquity
3001  00000 82 1502      radians
3002  00000 31 2000      → cosine routine
3003  00001 12 1504      cos angle obliquity
3004  00000 64 1503
3005  00000 83 1504
3006  00001 12 0407      secant angle obliquity
3007  00000 64 1501      thickness
3008  00001 12 0408
3009  00000 64 1505      plant exit
3010  00000 02 1045
3011  00000 20 1000      → interpolation
3012  00000 64 1500      ←
3013  00000 20 3020
3014  00000 64 1501      thickness
3015  00000 03 0610
3016  00000 64 1263
3017  00000 03 0610      range
3018  00000 08 9999
3019  00000 00 0000

3020  00000 03 0510
3021  00000 64 0407      secant angle obliquity
3022  00000 03 0610
3023  00000 20 3014
```

STORAGE

```
1500  00000 00 0000      angle obliquity
1501  00000 00 0000      thickness
1502  04917 45 3290      radian conversion factor
1503  05110 00 0000
1504  00000 00 0000      cosine storage
1505  00000 20 3012
```

THICKNESS PROGRAM

(OBLIQUITY AND RANGE FURNISHED)

3000	00000 64 1500	angle obliquity
3001	00000 32 1502	radians
3002	00000 31 2000	→ cosine routine
3003	00001 12 1504	
3004	00000 64 1503	
3005	00000 83 1504	
3006	00001 12 0408	secant angle obliquity
3007	00000 64 1501	range
3008	00001 12 0407	
3009	00000 64 1505	
3010	00000 02 1045	plant exit
3011	00000 20 1000	→ interpolation
3012	00000 64 1500	←
3013	00000 20 3020	
3014	00000 64 1501	range
3015	00000 03 0610	
3016	00000 64 1203	thickness
3017	00000 03 0610	
3018	00000 03 9999	
3019	00000 00 0000	
3020	00000 03 0510	
3021	00000 64 0403	
3022	00000 03 0610	
3023	00000 20 3014	

COSINE ROUTINE

```
2000  00000 80 7012
2001  00000 02 7020
2002  00000 74 7001
2003  00000 14 0004
2004  00000 02 2054
2005  00000 64 7000
2006  00000 83 7013
2007  00000 12 7000
2008  00000 80 7014
2009  00000 81 7014
2010  00000 81 7000
2011  00000 30 2015
2012  05115 70 7963
2013  15162 83 1853
2014  05810 00 0000
2015  00000 73 7020
2016  00000 28 7028
2017  00000 82 7030
2018  00000 12 7018
2019  00000 80 7031

2020  00000 81 7031
2021  00000 12 7021
2022  00000 63 7032
2023  00000 13 0007
2024  00000 02 2046
2025  00000 75 7021
2026  00000 80 7018
2027  00000 30 2034
2028  00000 80 7033
2029  00000 20 7017
2030  05140 00 0000
2031  05810 00 0000
2032  00010 00 0000
2033  05110 00 0000
2034  00000 02 7034
2035  00000 65 7034
2036  00000 12 7036
2037  00000 80 7047
2038  00000 02 7035
2039  00000 65 7035

2040  00000 02 7037
2041  00000 72 2046
2042  10000 64 7034
2043  00000 12 2055
2044  10000 82 7034
2045  00000 30 2048
2046  00000 00 0001
2047  05110 00 0000
2048  00000 02 7048
2049  00000 72 7061
2050  00000 82 7048
2051  10000 80 7056
2052  00000 22 7050
2053  00000 82 7055
2054  00270 20 3003
2055  05018 33 3350
2056  05115 70 7963
2057  15064 59 6371
2058  04979 68 9679
2059  14846 73 7656

2060  04715 14 8419
2061  00000 00 0004
2062  05634 23 2120
```

INTERPOLATION ROUTINE

```
1000  00000 30 1001
1001  00000 34 0000      Data in 4000
1002  00000 35 0400      Interpolation storage in 5000
1003  00000 36 0460      Interpolation in 6000
1004  00000 64 5009
1005  00000 02 0487      plant exit
1006  00000 20 6000      →
1007  00000 72 5001      ← secant interpolation
1008  10000 34 0000        Results in 1200 - 1505
1009  00000 64 5011
1010  00000 02 0487      plant exit
1011  00000 64 5014
1012  00000 02 5013
1013  00000 64 5008      thickness
1014  00000 02 5007
1015  00000 36 0460
1016  00000 20 6000      → thickness interpolation. Results in
1017  00000 72 1200      ← (lower curve)            1220-1225
1018  10000 34 0000      coded location data in 4000
1019  00000 30 1020

1020  00000 64 5012
1021  00000 02 0487      plant exit
1022  00000 64 5015
1023  00000 02 5013
1024  00000 36 0460
1025  00000 20 6000      → thickness interpolation. Results in
1026  00000 72 1220      ← (upper curve)            1240-1245
1027  10000 64 0000
1028  00000 32 0000
1029  10000 81 0000
1030  00000 82 1225
1031  10000 80 0000
1032  00001 12 1260      Range at secant and lower thickness
1033  00000 72 5000
1034  10000 64 0000
1035  00000 32 0000
1036  10000 81 0000
1037  00000 82 5005
1038  10000 80 0000
1039  00000 30 1040

1040  00000 12 1261      Range at secant and upper thickness
1041  00000 81 1260
1042  00000 82 1205
1043  00000 80 1260
1044  00001 12 1263      Range
1045  00000 20 3012
```

```
0460  00000 72 5010        z secant plus code for z ≤ x
0461  10000 64 4000
0462  00000 12 5001
0463  00000 63 5010
0464  00000 12 5002        z'
0465  00000 81 5007
0466  00000 73 5007
0467  00000 28 6010
0468  00000 32 0000
0469  00000 20 6001
0470  00000 22 6012
0471  00000 28 6018
0472  10000 64 4000
0473  00000 12 5000        y secant plus code y> x
0474  00000 63 5010
0475  00000 12 5003        y' (code removed)
0476  00000 81 5002        z' (code removed)
0477  00000 12 5006        y' - z'
0478  00000 36 0479
0479  00000 20 6000

0480  00000 64 5007        x                  x = value wanted
0481  00000 81 5002        z'                 y'= upper value
0482  00000 12 5004        x - z'             z'= lower value
0483  00000 83 5006        y' - z'
0484  00000 12 5005        R
0485  00000 72 5013
0486  10000 25 1200        Block to 1200's    R = (x - z') / (y' - z')
0487  00001 20 7006
```

INTERPOLATION STORAGE

```
0400  00000 00 0000
0401  00000 00 0000
0402  00000 00 0000
0403  00000 00 0000        } Temporary storage
0404  00000 00 0000
0405  00000 00 0000
0406  00000 00 0000
0407  00000 00 0000        x secant
0408  00000 00 0000        thickness
0409  00001 20 7007
0410  11111 11 0000
0411  00001 20 7017        } constants
0412  00001 20 7006
0413  00000 00 0000
0414  00000 00 0020
```

INPUT DATA STORAGE FOR INTERPOLATION FOR RANGE

0000 - 0019	Secant values and code (largest to smallest)
0020 - 0039	Thickness and range code @ 4.01
0040 - 0059	Thickness and range code @ 3.1
0060 - 0079	Thickness and range code @ 3.0
0080 - 0099	Thickness and range code @ 3.8
0100 - 0119	Thickness and range code @ 2.6
0120 - 0139	Thickness and range code @ 2.4
0140 - 0159	Thickness and range code @ 1.6
0160 - 0179	Thickness and range code @ 1.4
0180 - 0199	Thickness and range code @ 1.3
0200 - 0219	Thickness and range code @ 1.2
0220 - 0239	Thickness and range code @ 1.1
0240 - 0259	Thickness and range code @ 1.0
0620 - 0639	Range values @ 4.01
0640 - 0659	Range values @ 3.1
0660 - 0679	Range values @ 3.0
0680 - 0699	Range values @ 2.8
0700 - 0719	Range values @ 2.6
	etc.

SAMPLE INPUT DATA FOR RANGE

```
0000  05140 10 0020
0001  05131 00 0040
0002  05130 00 0060
0003  05128 00 0080
0004  05126 00 0100
0005  05124 00 0120
0006  05116 00 0140
0007  05114 00 0160
0008  05113 00 0180
0009  05112 00 0200
0010  05111 00 0220
0011  05110 00 0240
```

Secant values and code (largest to smallest)

FP	SECANT	STORAGE
xx	xxxx	xxxx

```
0020  05211 00 0620
0021  05140 00 0621
0022  05122 30 0622
0023  05114 50 0623
```

Thickness and range code @ 4.01

FP	SECANT	STORAGE
xx	xxxx	xxxx

```
0040  05211 00 0640
0041  05141 50 0641
0042  05130 70 0642
0043  05123 70 0643
0044  05095 00 0644
```

Thickness @ 3.1

```
0060  05211 00 0660
0061  05142 10 0661
0062  05131 50 0662
0063  05125 10 0663
0064  05112 00 0664
```

Thickness @ 3.0

```
0080  05211 00 0680
0081  05144 00 0681
0082  05133 60 0682
0083  05127 70 0683
0084  05116 80 0684
0085  05110 50 0685
```

Thickness @ 2.8

```
0100  05211 00 0700
0101  05146 70 0701
0102  05136 60 0702
0103  05130 70 0703
0104  05122 50 0704
0105  05112 70 0705
0106  05111 60 0706
```

Thickness @ 2.6

```
0120  05211 00 0720
0121  05150 70 0721
0122  05141 20 0722
0123  05134 50 0723
0124  05128 20 0724
0125  05120 20 0725
0126  05116 30 0726
0127  05112 70 0727
0128  05085 00 0728
```

Thickness @ 2.4

```
0140  05211 00 0740
0141  05171 50 0741
0142  05163 20 0742
0143  05156 80 0743
0144  05150 20 0744
0145  05142 60 0745
0146  05137 20 0746
0147  05132 70 0747
0148  05129 10 0748
```

Thickness @ 1.6

```
0160  05211 00 0760
0161  05179 70 0761
0162  05170 30 0762
0163  05163 70 0763
0164  05156 60 0764
0165  05149 20 0765
0166  05143 20 0766
0167  05139 00 0767
0168  05135 30 0768
```

Thickness @ 1.4

```
0180  05211 00 0780
0181  05183 00 0781
0182  05176 30 0782
0183  05168 70 0783
0184  05161 30 0784
0185  05153 20 0785
0186  05147 00 0786
0187  05142 90 0787
0188  05139 00 0788
```

Thickness @ 1.3

```
0200  05211 00 0800
0201  05192 20 0801
0202  05183 80 0802
0203  05176 00 0803
0204  05168 00 0804
0205  05159 50 0805
0206  05153 00 0806
0207  05147 70 0807
0208  05143 60 0808
```

Thickness @ 1.2

```
0220  05211 00 0820
0221  05210 05 0821
0222  05193 60 0822
0223  05186 00 0823
0224  05178 20 0824
0225  05169 20 0825
0226  05162 50 0826
0227  05152 90 0827
0228  05151 00 0828
```

Thickness @ 1.1

```
0240  05211 00 0840
0241  05210 95 0841
0242  05210 70 0842
0243  05210 10 0843
0244  05192 00 0844
0245  05189 50 0845
0246  05183 00 0846
0247  05172 70 0847
0248  05166 80 0848
```

Thickness @ 1.0

```
0620  05000 00 0000
0621  05000 00 0000
0622  05350 00 0000
0623  05410 00 0000
```

Range values @ 4.01

```
FP   RANGE
xx    xxxx  0000
```

```
0640  05000 00 0000
0641  05000 00 0000
0642  05350 00 0000        Range @ 3.1
0643  05410 00 0000
0644  05415 00 0000
```

```
0660  05000 00 0000
0661  05000 00 0000
0662  05350 00 0000        Ranges @ 3.0
0663  05410 00 0000
0664  05415 00 0000
```

```
0680  05000 00 0000
0681  05000 00 0000
0682  05350 00 0000
0683  05410 00 0000        Ranges @ 2.8
0634  05415 00 0000
0685  05420 00 0000
```

```
0700  05000 00 0000
0701  05000 00 0000
0702  05350 00 0000
0703  05410 00 0000        Ranges @ 2.6
0704  05415 00 0000
0705  05420 00 0000
0706  05425 00 0000
```

```
0720  05000 00 0000
0721  05000 00 0000
0722  05350 00 0000
0723  05410 00 0000
0724  05415 00 0000        Ranges @ 2.4
0725  05420 00 0000
0726  05425 00 0000
0727  05430 00 0000
0728  05435 00 0000
```

```
0740  05000 00 0000
0741  05000 00 0000
0742  05350 00 0000
0743  05410 00 0000
0744  05415 00 0000
0745  05420 00 0000
0746  05425 00 0000
0747  05430 00 0000
0748  05435 00 0000
```

Ranges @ 1.6

```
0760  05000 00 0000
0761  05000 00 0000
0762  05350 00 0000
0763  05410 00 0000
0764  05415 00 0000
0765  05420 00 0000
0766  05425 00 0000
0767  05430 00 0000
0768  05435 00 0000
```

Ranges @ 1.4

```
0780  05000 00 0000
0781  05000 00 0000
0782  05350 00 0000
0783  05410 00 0000
0784  05415 00 0000
0785  05420 00 0000
0786  05425 00 0000
0787  05430 00 0000
0788  05435 00 0000
```

Ranges @ 1.3

```
0800  05000 00 0000
0801  05000 00 0000
0802  05350 00 0000
0803  05410 00 0000
0804  05415 00 0000
0805  05420 00 0000
0806  05425 00 0000
0807  05430 00 0000
0808  05435 00 0000
```

Ranges @ 1.2

```
0820  05000 00 0000
0821  05000 00 0000
0822  05350 00 0000
0823  05410 00 0000
0824  05415 00 0000
0825  05420 00 0000
0826  05425 00 0000
0827  05430 00 0000
0828  05435 00 0000
```

Ranges @ 1.1

```
0840  05000 00 0000
0841  05000 00 0000
0842  05350 00 0000
0843  05410 00 0000
0844  05415 00 0000
0845  05420 00 0000
0846  05425 00 0000
0847  05430 00 0000
0848  05435 00 0000
```

Ranges @ 1.0

INPUT DATA STORAGE FOR INTERPOLATION FOR THICKNESS

0000 - 0019	Range values and Code (largest to smallest)
0020 - 0039	Secants and Code @ 3500 meters
0040 - 0059	Secants and Code @ 3000 meters
0060 - 0079	Secants and Code @ 2500 meters
0080 - 0099	Secants and Code @ 2000 meters
0100 - 0119	Secants and Code @ 1500 meters
0120 - 0139	Secants and Code @ 1000 meters
0140 - 0159	Secants and Code @ 0500 meters
0160 - 0179	Secants and Code @ 0 meters
0620 - 0639	Thickness @ 3500 meters
0640 - 0659	Thickness @ 3000 meters
0660 - 0679	Thickness @ 2500 meters
	etc.

SAMPLE CURVE DATA FOR THICKNESS

```
0000  05435 00 0020
0001  05430 00 0040
0002  05425 00 0060
0003  05420 00 0080
0004  05415 00 0100
0005  05410 00 0120
0006  05350 00 0140
0007  05000 00 0160

0020  05123 40 0620
0021  05120 00 0621
0022  05118 00 0622
0023  05114 00 0623
0024  05112 00 0624
0025  05111 00 0625
0026  05110 00 0626

0040  05125 30 0640
0041  05122 00 0641
0042  05118 00 0642
0043  05114 00 0643
0044  05113 00 0644
0045  05112 00 0645
0046  05111 00 0646
0047  05110 00 0647

0060  05125 30 0660
0061  05122 00 0661
0062  05118 00 0662
0063  05114 00 0663
0064  05113 00 0664
0065  05112 00 0665
0066  05111 00 0666
0067  05110 00 0667

0080  05128 10 0680
0081  05122 00 0681
0082  05118 00 0682
0083  05114 00 0683
0084  05113 00 0684
0085  05112 00 0685
0086  05111 00 0686
0087  05110 00 0687
```

Range and code (largest to smallest)

FP	Range	Storage
xx	xxxx	xxxx

Secants and code @ 3500 meters

FP	Secants	Storage
xx	xxxx	xxxx

Secants and code @ 3000 meters

Secants and code @ 2500 meters

Secants and code @ 2000 meters

```
0100  05130 80 0700
0101  05122 00 0701
0102  05116 00 0702
0103  05114 00 0703
0104  05113 00 0704
0105  05112 00 0705
0106  05111 00 0706
0107  05110 00 0707
```

Secants and code @ 1500 meters

```
0120  05140 00 0720
0121  05132 00 0721
0122  05125 00 0722
0123  05118 00 0723
0124  05114 00 0724
0125  05113 00 0725
0126  05112 00 0726
0127  05111 00 0727
0128  05110 00 0728
```

Secants and code @ 1000 meters

```
0140  05140 00 0740
0141  05132 00 0741
0142  05126 00 0742
0143  05120 00 0743
0144  05115 00 0744
0145  05114 00 0745
0146  05113 00 0746
0147  05112 00 0747
0148  05111 00 0748
0149  05110 00 0749
```

Secants and code @ 500 meters

```
0160  05140 00 0760
0161  05134 00 0761
0162  05130 00 0762
0163  05126 00 0763
0164  05120 00 0764
0165  05116 00 0765
0166  05114 00 0766
0167  05113 00 0767
0168  05112 00 0768
0169  05111 00 0769
0170  05110 00 0770
```

Secants and code @ 0 meters

```
0620  05110 00 0000
0621  05119 00 0000
0622  05124 00 0000
0623  05135 00 0000
0624  05143 50 0000
0625  05151 00 0000
0626  05167 00 0000
```

Thickness @ 3500 meters

```
0640  05110 00 0000
0641  05117 50 0000
0642  05127 50 0000
0643  05139 00 0000
0644  05143 00 0000
0645  05147 50 0000
0646  05155 50 0000
0647  05173 00 0000
```

Thickness @ 3000 meters

```
0660  05110 00 0000
0661  05121 50 0000
0662  05132 00 0000
0663  05143 00 0000
0664  05147 00 0000
0665  05153 00 0000
0666  05162 00 0000
0667  05182 50 0000
```

Thickness @ 2500 meters

```
0680  05110 00 0000
0681  05125 70 0000
0682  05137 00 0000
0683  05149 30 0000
0684  05153 50 0000
0685  05159 50 0000
0686  05169 00 0000
0687  05189 50 0000
```

Thickness @ 2000 meters

```
0700  05110 00 0000
0701  05134 00 0000
0702  05150 00 0000
0703  05156 50 0000
0704  05161 50 0000
0705  05168 00 0000
0706  05178 00 0000
0707  05194 50 0000
```

Thickness @ 1500 meters

```
0720  05114 50 0000
0721  05122 50 0000
0722  05132 50 0000
0723  05151 00 0000
0724  05163 50 0000
0725  05168 50 0000
0726  05176 00 0000
0727  05186 00 0000
0728  05210 10 0000
```

Thickness @ 1000 meters

```
0740  05122 50 0000
0741  05130 00 0000
0742  05136 50 0000
0743  05152 00 0000
0744  05167 00 0000
0745  05171 00 0000
0746  05176 50 0000
0747  05184 00 0000
0748  05194 00 0000
0749  05210 70 0000
```

Thickness @ 500 meters

```
0760  05140 00 0000
0761  05140 50 0000
0762  05142 00 0000
0763  05146 50 0000
0764  05160 50 0000
0765  05171 50 0000
0766  05180 00 0000
0767  05185 50 0000
0768  05192 50 0000
0769  05210 00 0000
0770  05211 00 0000
```

Thickness @ 0 meters

APPENDIX D

SAMPLE OUTPUT

SAMPLE OF RANGE DETERMINATION (ANGLES AND THICKNESS KNOWN)

FRONTAL ATTACK

Hor angle	Cos hor angle	Vert angle	Cos vert angle	Cos angle obliq	Sec angle obliq	Thickness	Range(m)	Range(yds)
+5000000000	5110000000	5224500000	5090996137	5090996137	5110989477	5169400000	5419875774	5421736365
+5000000000	5110000000	5237500000	5079335351	5079335351	5112604721	5157500000	5422415946	5424514325
+5000000000	5110000000	5274500000	5026723865	5026723865	5137419737	5128100000	5372201420	5378960267
+5230000000	5086602550	5225000000	5090630793	5078488577	5112740708	5151900000	5429062519	5431783090
+5230000000	5086602550	5236000000	5080901715	5070062949	5114272879	5146300000	5429201920	5431935540
+5230000000	5086602550	5252000000	5061566169	5053317872	5118755437	5133100000	5428624958	5431304568
+5245000000	5070710703	5224000000	5091354553	5064597450	5115480487	5145900000	5425089220	5427437846
+5245000000	5070710703	5237000000	5079863565	5056472088	5117707863	5140900000	5423148683	5425315654
+5245000000	5070710703	5246000000	5069465861	5049119798	5120358391	5135800000	5420428903	5422341273
+5267500000	5038268373	5224000000	5091354558	5034959903	5128604198	5136900000	5337100466	5340573477
+5267500000	5038268373	5228000000	5088294772	5033788972	5129595457	5135200000	5346995121	5351394381
+5267500000	5038268373	5237000000	5079863565	5030562486	5132719854	5132300000	5355098494	5360256319

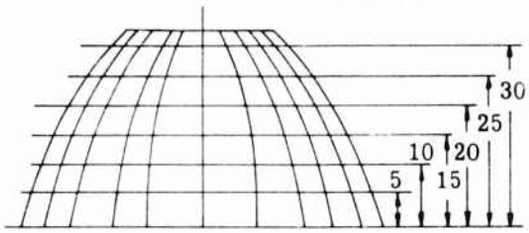
SAMPLE OF RANGE DETERMINATION (ANGLES AND THICKNESS KNOWN)

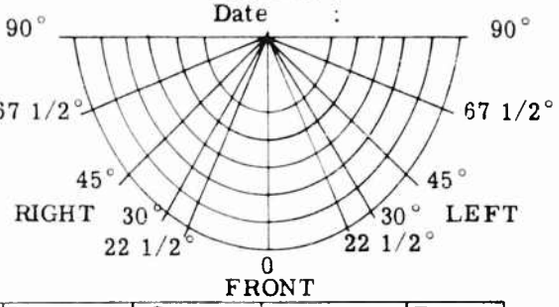
30° FLANK ATTACK

Hor angle	Cos hor angle	Vert angle	Cos vert angle	Cos angle oblig	Sec angle oblig	Thickness	Range(m)	Range(yds)
+5230000000	5086602550	5224500000	5090996137	5070804975	5112639554	5169400000	5410650697	5411866441
+5230000000	5086602550	5237500000	5079335351	5068700437	5114554677	5157500000	5417308660	5418928940
+5230000000	5086602550	5274500000	5026723865	5023143548	5143268589	5128100000	5354925053	5360066042
+5000000000	5110000000	5225000000	5090630793	5090630793	5111033777	5151900000	5445028626	5449235051
+5000000000	5110000000	5236000000	5080901716	5080901716	5112360677	5146300000	5440023063	5443775786
+5000000000	5110000000	5252000000	5061566169	5061566169	5116242666	5133100000	5438039269	5442311032
+5215000000	5096592594	5224000000	5091354558	5083241737	5111332506	5145900000	5445167730	5449395926
+5215000000	5096592594	5237000000	5079863565	5077142269	5112903058	5140900000	5445193148	5449423723
+5215000000	5096592594	5246000000	5069465861	5067098877	5114903379	5135800000	5441630722	5445527515
+5237500000	5079335351	5224000000	5091354558	5072476459	5113797583	5136900000	5445776724	5450061928
+5237500000	5079335351	5228000000	5088294772	5070048967	5114275728	5135200000	5446708767	5451081221
+5237500000	5079335351	5237000000	5079863565	5063360039	5115782819	5132300000	5442639893	5446631456
+5260000000	5050000025	5215000000	5096592594	5048296321	5120705511	5128800000	5428333051	5430985336
+5260000000	5050000025	5218500000	5094832375	5047416211	5121089834	5128400000	5428070748	5430698478
+5260000000	5050000025	5233000000	5083867073	5041933557	5123847250	5125800000	5424980289	5427318718

VEHICLE
ARMAMENT PROTECTION:
ATTACK : 30° FLANK
SIDE : LEFT

BY :
Apprv'd. :
Date :





Ref. Point		Horiz. Ang. Deg	Cos. Horiz. Angle	Vert. Ang Deg	Cos. Vert. Angle	Cos. Angle Obliquity	Secant Angle Obq	Thickness 100%	Thickness 95%	Range Yards
0°	25									
	30									
22 1/2°	5	34.5		22						
	10									
	15	48.5		20						
	20	49		42.5						
	25	46.5		64.5						
	30									
30°	5	38		17						
	10	45.5		9						
	15	48.5		25.5						
	20	49.5		39						
	25	47		57						
	30									
45°	5	44		10.5						
	10	49		22						
	15	51		30.5						800
	20	52.5		38						
	25	48.5		50.5						
	30									
67 1/2°	5	62		30						
	10	67.5		35.5						
	15	67.5		37.5						
	20	68.5		37.5						
	25	67.5		36.5						
	30									
90°	5									
	10									
	15									
	20									
	25									
	30									

FIGURE D-1. INPUT DATA SAMPLE FOR THICKNESS

SAMPLE OF THICKNESS DETERMINATION (ANGLES AND RANGE KNOWN)

30° LEFT FLANK ATTACK

[illegible] angle	Cos hor angle	Vert angle	Cos vert angle	Cos angle obliq	Sec angle obliq	Range(m)	Range(yds)	Thickness
+5254500000	5082412633	5222000000	5092718395	5076411670	5113017006	5373152150	5379999995	5172679058
+5248500000	5066262030	5220000000	5093969274	5062265948	5116060143	5373152150	5379999995	5162300101
+5249000000	5065605920	5242500000	5073727749	5048369768	5120674070	5373152150	5379999995	5148281667
+5246500000	5068835477	5264500000	5043051134	5029634453	5133744508	5373152150	5379999995	5130136147
+5238000000	5078801088	5217000000	5095630480	5075357858	5113270017	5373152150	5379999995	5172066028
+5245500000	5070090943	5190000000	5098768836	5069228008	5114445021	5373152150	5379999995	5167939867
+5248500000	5066262030	5225500000	5090258543	5059807142	5116720412	5373152150	5379999995	5160363257
+5249500000	5064944829	5239000000	5077714611	5050471621	5119813114	5373152150	5379999995	5150992080
+5247000000	5068199861	5257000000	5054463923	5037144319	5126922019	5373152150	5379999995	5134976510
+5244000000	5071934003	5210500000	5098325492	5070729462	5114138380	5373152150	5379999995	5169098119
+5249000000	5065605920	5222000000	5092718395	5060828756	5116439593	5373152150	5379999995	5161187016
+5251000000	5062932072	5230500000	5086162933	5054224119	5118441977	5373152150	5379999995	5155240306
+5252500000	5060876161	5238000000	5078801088	5047971077	5120845894	5373152150	5379999995	5147738367
+5248500000	5066262030	5250500000	5063607850	5042147852	5123726003	5373152150	5379999995	5140054735
+5262000000	5046947183	5230000000	5086602550	5040657457	5124595735	5373152150	5379999995	5138403852
+5267500000	5038268373	5235500000	5081411575	5031154885	5132097695	5373152150	5379999995	5131094185
+5267500000	5038268373	5237500000	5079335351	5030360348	5132937699	5373152150	5379999995	5130605510
+5268500000	5036650155	5237500000	5079335351	5029076529	5134392000	5373152150	5379999995	5129759466
+5267500000	5038268373	5236500000	5080385702	5030762300	5132507323	5373152150	5379999995	5130855882

APPENDIX E

SAMPLE RANGE-SECANT-THICKNESS CURVES

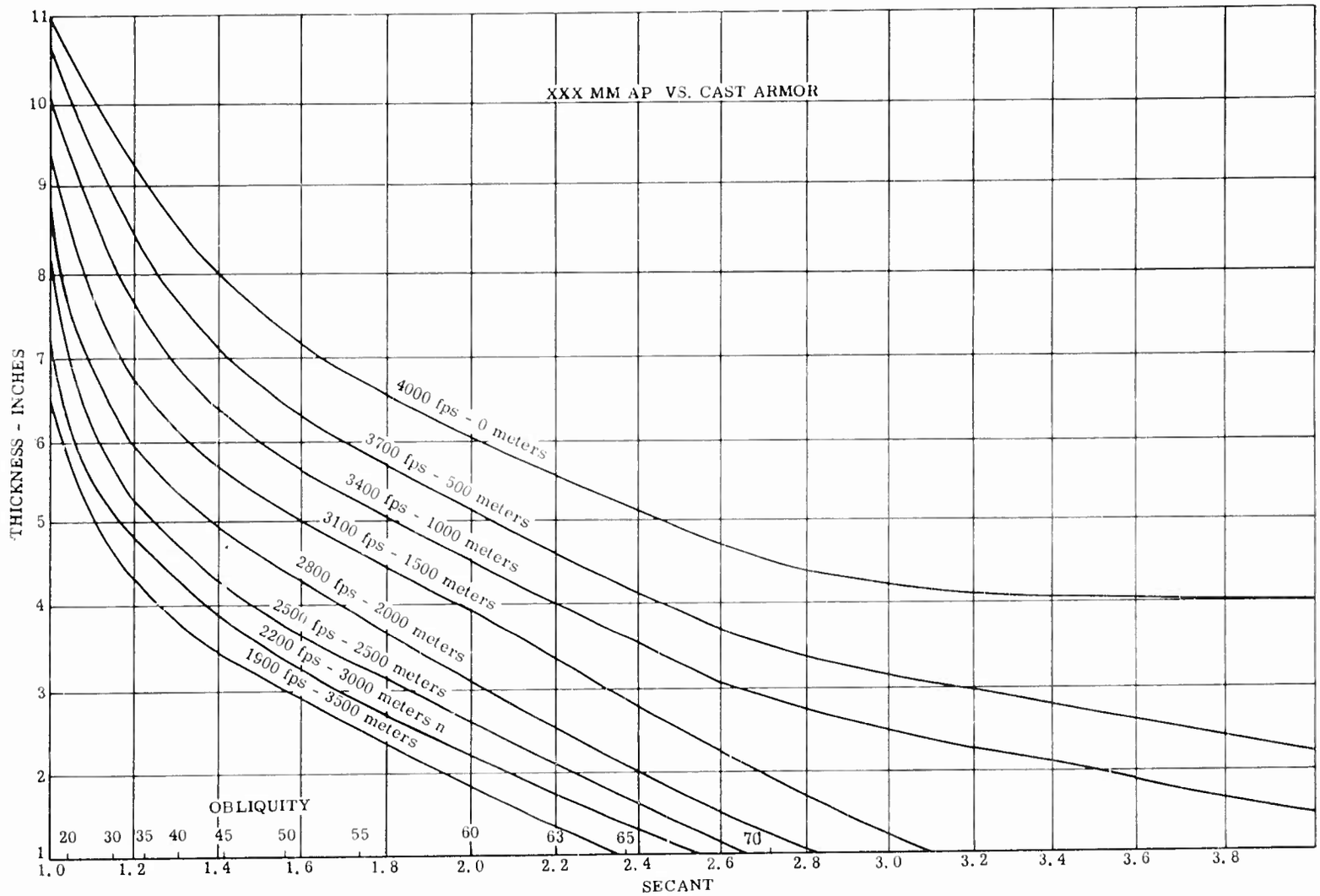


FIGURE E-1. SAMPLE RANGE-SECANT-THICKNESS CURVES

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RR-9	Digital Computer Program for Acceleration Performance, Wheeled Vehicles
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This report presents a digital computer program for (1) determining the range at which an armored vehicle is vulnerable to rounds striking a specified point on its surface and for (2) determining the armor thickness required for protection at a specified range and angle of attack.

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